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An effective blended online teaching and learning strategy during the COVID-19 pandemic

Lorico DS. Lapitan Jr.[a,b,*], Cristina E. Tiangco[a,b], Divine Angela G. Sumalinog[a], Noel S. Sabarillo[a], Joey Mark Diaz[c]

[a] Department of Chemical Engineering, Faculty of Engineering, University of Santo Tomas, Manila, Philippines
[b] Research Center for the Natural and Applied Sciences, Manila, Philippines
[c] Leeds Institute of Medical Research, School of Medicine, University of Leeds, Leeds West Yorkshire, United Kingdom

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ABSTRACT

The shift to distance teaching and learning during the COVID-19 pandemic brought about a real challenge for both instructors and students. To face these difficulties in teaching undergraduate Chemistry courses at the University of Santo Tomas, a blended learning strategy in the context of teaching and learning of Physical Chemistry 1 and Analytical Chemistry for Chemical Engineering students were employed. Here, we present an online strategy that facilitated the transition from traditional face-to-face learning to full online instruction. This is a five-component blended learning strategy referred to as Discover, Learn, Practice, Collaborate and Assess (DLPCA). In DLPCA, the asynchronous part of the teaching was achieved through broadcast of pre-recorded lecture videos on YouTube to allow students to study and progress with learning at their own pace. The synchronous part of the teaching was conducted using video conferencing platforms, such as Zoom or Google Meet. The DLPCA strategy was presented and discussed to the students prior to its implementation. The analysis of the teaching and learning experience based on three indicators (i) student's learning experience, (ii) student's academic performance and (iii) instructor observations showed that DLPCA had a positive impact on students and instructors. The identified challenges were stability of internet connection and instructor's familiarity with readily available internet-based teaching tools, such as video conferencing software. Instructors must also find means to improve their interaction with students and maintain student interest and engagement during online classes. The survey also indicated that most of the students are satisfied with the DLCPA strategy. Hence, this strategy is considered a manageable and effective alternative that can be adapted to full online instruction to other undergraduate Chemistry lecture courses. Overall, the findings and insights in this study will add valuable resources for further hybrid instruction in the post-COVID-19 time in higher education.

1. Introduction

1.1. Context of the study

The Coronavirus Disease 2019 (COVID-19) pandemic has dramatically changed the higher education system in the Philippines with a distinctive shift in online instruction as an effort to limit further transmission of the virus. This sudden change to online instruction raised concern among many teachers and students because a large segment of the population have unstable internet access and limited electronic devices (Pastor, 2020; Mirandilla-Santos, 2016). Since the pandemic started and presently shows little signs of declining, worries whether internet connection would not suffice to support online education persist as a challenge. Undergraduate Chemical Engineering students are required to take Analytical Chemistry and Physical Chemistry 1 courses during their first and second year of studies at universities in the Philippines. The Physical Chemistry 1 curriculum for Chemical Engineering undergraduate students includes topics in properties of gases, laws of thermodynamics, and phase equilibria. The Analytical Chemistry course includes topics in chemical equilibrium, classical quantitative analysis, and instrumental methods analysis.

The second term of the academic year (AY) 2019–2020, which is from January to May 2020, at the University of Santo Tomas (UST)

* Corresponding author at: Department of Chemical Engineering, Faculty of Engineering, University of Santo Tomas, Manila, Philippines.
E-mail address: ldlapitan@ust.edu.ph (L.DS. Lapitan Jr.).

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was indefinitely suspended at around March due to the steadily increasing COVID-19 cases in Metro Manila, risks and local transmission concerns of COVID-19. This led to all courses being advised to shift online until the end of the second term. Due to the projected continuous increase of cases, it was also later decided by the University that online classes will be implemented until the first semester of AY 2020–2021 (August to December 2020). The sudden shift to full online instruction led faculty members to adjust their teaching plans, teaching styles and assessment methods. Students also faced the challenge to quickly adapt to the "new normal" in higher education setting. The shift to online instruction was a contingency plan to secure the continuation of the courses offered by the University and enable students to continue with their studies. However, developing countries, like the Philippines, have areas that do not have a reliable or existent internet connection which posed a great and major challenge to the shift to full online instruction.

As the immediate future is uncertain with new outbreaks and looming lockdowns, many instructors had to consider online instruction, which can be given in one of three pedagogical approaches: (1) synchronous, (2) asynchronous and (3) blended learning strategy. In synchronous online lectures (real-time), instructors and students meet online using a video conferencing software during the designated class hours and instructors give lectures on the course. Students participate in the lectures and are able to ask questions vocally or *via* live text chat. In asynchronous lectures, instructors record lecture videos and upload them in Blackboard learning management system (LMS) or YouTube, so that students can access them in their most convenient time.

The blended online learning strategy is deemed to be the most practical method to adapt as this combines the advantages of synchronous and asynchronous strategies. The main motivation in choosing the blended strategy is to increase the student's participation in their own learning process rather than quietly sitting during a synchronous discussion. The basis of this approach is the cognitive load theory, on the basis that novice learners are immediately overwhelmed by a large amount of new ideas and terminologies, and resort to surface learning (Darabi and Jin, 2013; Seery and Donnelly, 2012; Seery, 2013). This type of active learning pedagogy is called "flipped classroom" approach (Bergmann and Sams, 2012; Olakanmi, 2017). In this learning approach, traditional lecture and homework are replaced by pre-class activities, such as viewing short, pre-recorded lecture videos. The class time is devoted to further reinforce the topics through problem solving examples, interactive activities and detailed discussions (Pienta, 2016; Rau et al., 2017). However, the synchronous online class sessions (called the "virtual classroom") replaced the traditional face-to-face class for engaging the students with activities and guided problem-solving discussions in the traditional flipped classroom.

The benefits from flipped classroom were reported by economists (Lage et al., 2000). Lage and colleagues showed that reducing variability in teaching styles across classroom and implementing various activities to create an inclusive classroom resulted to an improved student performance (Lage et al., 2000). Several other disciplines have reported a similar success with implementing the flipped learning in materials science courses (Liou et al., 2016), pharmacy (Koo et al., 2016), statistics (Peterson, 2016), engineering education (Kerr, 2015; Chiquito et al., 2020), computer science (Sohrabi and Traj, 2016; Davies et al., 2013), and health science courses (Betihavas et al., 2016; McLaughlin et al., 2014). In chemistry, flipped classrooms were first introduced in a high school general chemistry curriculum (Bergmann and Sams, 2012). There are several literatures that discuss the benefits that can be accrued from flip learning in chemistry courses with most of the examples presented involve high school general chemistry (Bergmann and Sams, 2012; Schultz et al., 2014). Moreover, substantial amount of work has been published on the effectiveness of the flipped classroom when implemented higher education chemistry courses such as General chemistry, Organic chemistry, and Biochemistry (Smith, 2013; Fautch, 2015; Seery, 2015; Mooring et al., 2016; Ojennus, 2016; Bokosmaty et al., 2019). Interestingly, reports published about the effectiveness of flipped learning in calculation intensive courses such as Analytical Chemistry and Physical Chemistry are scarce (Fitzgerald and Li, 2015; Esson, 2016). Therefore, it is important for this paper to contribute to this current information gap.

1.2. Course format

The next focus of the instructors was to organize and deliver the content to achieve the learning objectives of the course. Unlike in some developed countries where teaching is designed with the assumption that all the students have equal technical and cultural resources to access academic materials, developing countries, such as the Philippines, must give high consideration on the socio-technical constraints of all students when designing the course content and delivery.

The Discover, Learn, Practice, Collaborate and Assess (DLPCA) strategy was conceptualized for this blended learning technique with the goal of integrating the instructors, students, and readily available technologies to meet the challenges of higher education during this pandemic. Fig. 1 shows the five (5) components of DLCPA with a brief explanation of each component. Students were first asked to *discover* all learning materials prepared for the assigned topic which were uploaded in the UST Blackboard LMS (Fig. 1a). Next, the students are expected to *learn* the terminologies, concepts, and calculations through the pre-recorded lecture videos and other materials provided, such as notes, web links to other resources (e.g. Khan Academy, ChemLibreText), and chemistry infographics (Fig. 1b). The *practice* component allows students to apply what they learned using the self-assessment questions (SAQs) (Fig. 1c). Students are given enough time to view short, pre-recorded video lectures and answer the SAQs before joining the online class session. The class time is devoted for students to *collaborate* in doing interactive activities, such as quiz bees and discussions (Fig. 1d). The synchronous online sessions were used to discuss and clarify specific aspects of the concepts and calculations that students found difficult to understand. The collaborate component is expected to positively impact student engagement with the instructor and peer learning. Finally, the *assess* component are quizzes or exams that are given with allotted time to test the student's comprehension of the topics based on the declared intended course learning outcomes (Fig. 1e).

Online lectures are not very common in most universities in the Philippines and chemistry lectures are generally given in classroom settings. The COVID-19 pandemic undeniably accelerated the process of transition to full online instruction and provided opportunities to carry out effective online teaching. It is worthwhile to examine if the implemented DLPCA strategy is an effective method for full online instruction. By collecting the experiences of the authors and students who have worked and studied during the COVID-19 pandemic, we aim to provide a better understanding on how the DLPCA strategy enabled teachers and students to rise to the challenges of online instruction given the resources and technologies present at the time. Specifically, we investigated three important aspects of online instruction, namely: (i) online content delivery strategy, (ii) learning mechanisms (synchronous and asynchronous), and (iii) assessment type and strategies. The results presented in this paper will provide a preliminary basis on the adaption of DLPCA strategy in online undergraduate Analytical chemistry and Physical chemistry courses and will help build a

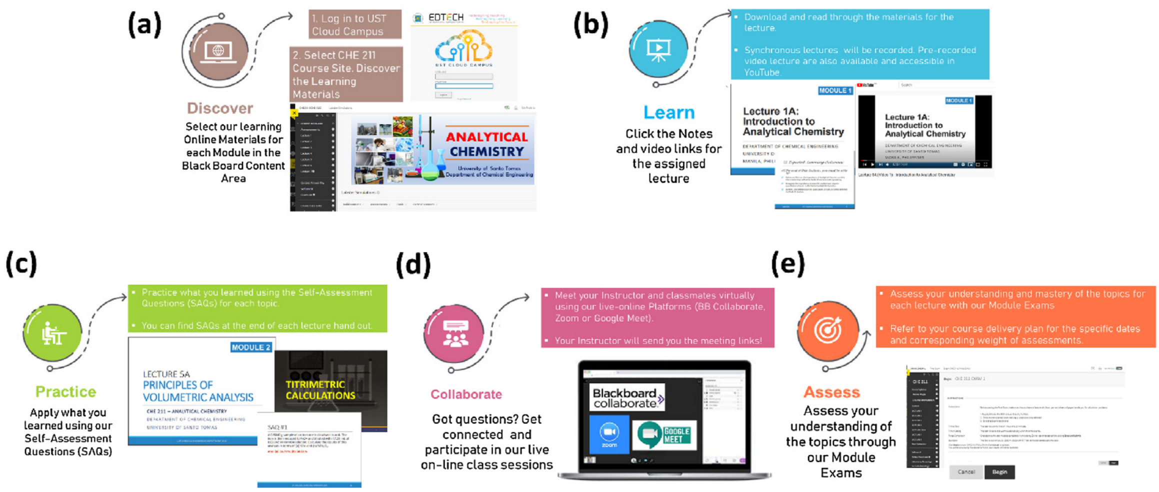

Fig. 1. The 5 components of the DLPCA strategy – (a) *Discover*, (b) *Learn*, (c) *Practice*, (d) *Collaborate*, and (e) *Assess*.

strong foundation for future pedagogical decisions regarding online instruction.

2. Methodology

2.1. Equipment and software for recorded lecture videos

Recorded lecture videos are a very important part of DLPCA strategy which were given to students before attending the synchronous sessions. Lecture videos were made simple, readable, visually appealing, understandable, and easily accessible for students. Narrations or discussions were recorded using Microsoft PowerPoint and was saved as MP4 file. Sound quality adjustments, if necessary, and the addition of introductory and end music animations were done using Movavi video editor software. The lecture videos were then uploaded on YouTube for accessibility and the links were given to students through Blackboard.

2.2. Evaluation and data collection

This study was based on a survey of students who experienced online instruction using the DLPCA strategy. The questionnaires were designed with the aim to understand their opinions on chemistry online teaching and learning, if the students are aware of the DLCPA strategy, impact of online strategy on them, and as well as their satisfaction with the online teaching strategy during the COVID-19 pandemic. The survey was made using the google form and composed mainly of Likert scale questions where the participants indicate their level of agreement or disagreement on statements that cover general feedback on the various aspects of the course. The questionnaire is based on a 5-point Likert scale which are as follows: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), and 5 (strongly agree). The last section of the questionnaire also invited students' feedback and sentiments through open-ended questions. To assess the internal consistency of the Likert scale questions, Chronbach's alpha was calculated (Supplemental Information, SI-1). This measures how well a questionnaire measures a variable based on a set of questions like those in a Likert scale (Tavakol and Dennick, 2011; Glen, 2021). Pretesting of the questionnaire was administered to 59 respondents and yielded a Cronbach's alpha of 59%–88% implying that the questionnaire's reliability is acceptable (Taber, 2018). Data gathering which took place at the end of the second term for Physical chemistry 1 (May 2020) and Special Term for Analytical chemistry (July 2020). The UST course codes for Physical Chemistry 1 and Analytical Chemistry are CHE 216 and CHE 211, respectively. These course codes were used in the questionnaire. The google form link containing the questionnaire was sent to the students through their university email accounts. Responses were received over a period of one week.

Table 1
Interpretation of responses of the Likert-type scale.

Mean Range	Interpretation
1 to 1.80	Strongly disagree
1.81 to 2.60	Disagree
2.61 to 3.40	Neutral
3.41 to 4.20	Agree
4.21 to 5.00	Strongly agree

2.3. Data processing

Descriptive statistics using frequency, percentage, and means, were calculated from the responses to 5-point Likert scale questions. Mean response for each item in the construct variables, as well as the overall mean response per construct variable were calculated and then interpreted using the guide shown in Table 1 (Sözen and Güven, 2019).

For the open-ended questions, we then performed a text mining and word cloud analysis using R software using a package called *tm* (Feinerer and Hornik, 2019; Feinerer et al., 2008). This comes with an available tutorial published by the Statistical Tool for High-throughput Data Analysis website (STHDA, 2020). This package allowed us to determine the most frequently used keywords in the 3 open-ended questions in the survey. We also removed punctuation, common stop words such as "there", "as", "and" "the" and non-printable characters such as emojis in the comments metadata. A word cloud was generated to have a visual representation of the data. The word cloud is an image made of words and the size of the word corresponds to how it often appears (frequency) the students answer in the open-ended questions.

Visualisation of the scores in the four quizzes in CHE 211 during the online term was done using box plots. Analysis of variance (ANOVA) was used to compare the scores of the students among the four quiz periods. Post-hoc test using Tukey's LSD was used to identify which among quiz scores are significantly different. Welch *t*-test was used to compare the final grade of students between online and face-to-face classes in CHE 211. All tests are performed at 95 % confidence level.

2.4. Participants

The questionnaires were answered by Chemical engineering student majors enrolled in Physical chemistry 1 (N = 77) and Analytical chemistry (N = 91) during the second and special term of AY 2019–2020. The students were informed about the purpose of this questionnaire and were aware that the data would be used only for research and academic purposes. The participants responded in the survey anonymously. The empirical data were gathered and analysed. Initial results showing frequency and percentages of response in each Likert type question were automatically generated by the Google form.

3. Results and discussion

3.1. Development of the teaching approach in online classroom instruction in chemistry

3.1.1. Educational theory

Several factors were considered in designing the appropriate teaching approach for Analytical chemistry and Physical chemistry. One is by evaluating the proper pedagogical model to use. Among the main learning theories, the cognitivism and constructivism approach are deemed to apply best in the online classroom setting. The concept of cognitivism focuses on the stimulation of the student's learning strategies (Acevedo et al., 2020). It describes the idea that students process the information that they receive and reorganizes them to gain and store new knowledge. This is promoted through practical discussions and problem solving. On the other hand, constructivism focuses on the idea that students acquire new information by building on their previous knowledge and experience through a series of various activities and assessments (Ripoll et al., 2021). In DLPCA strategy, new information is given in a module-based approach wherein the concepts are linked and built from previous modules. The discussions do not only revolve around the technical topic at hand, but also on practical applications or real-world problems. Assessments are given to challenge their understanding and problem-solving skills. These strategies are believed to be enough to provide learnings to students as these methods also address the conception of learning most applicable to this situation. Negovan et al. (2015) found that students, whether in a face-to-face or distant learning setting, highly regard learning as understanding, which incorporates increasing one's knowledge, memorizing, and applying what was learned. The proposed DLPCA strategy combines these theories and concepts with the goal of maximum learning for the students through its course content, delivery and assessments.

3.1.2. Socio-technical constraints in online teaching and learning

Designing an effective teaching and learning strategy not only requires the study of different pedagogies, but also the consideration of the students' and instructors' current social and technical conditions amidst the on-going pandemic. The different constraints and difficulties experienced by students and instructors alike were first identified. The following constraints were considered in designing the DLPCA:

a) Due to the unpredicted and short notice of lockdown in the middle of March 2020, most students went home and left their textbooks and other learning materials in their school lockers and/or dormitories.
b) Students may have technical and personal constraints that may prevent them from online learning during the lockdown, such as lack of computers/laptops or other gadgets, lack of stable internet access, power interruptions, lack of quiet and isolated room to study, slow and old computers, non-academic responsibilities within the family, and some students may need necessary medical appointments.
c) Asynchronous teaching materials must be made accessible for all students. The differences in the availability and speed of internet connection of the students must be considered.
d) Physical Chemistry and Analytical Chemistry courses involve a lot of calculations which must be properly taught to students. The online delivery of lectures may pose a challenge in effectively communicating concepts and theories to students.
e) There is an imminent overload of internet networks due to the large number of students doing online learning and most employees are in a work-from-home arrangement. It is therefore necessary to choose a stable, free of charge, and universally accessible platform for online synchronous class discussions. Moreover, this platform must have the following capabilities: (i) call encryption for security, (ii) screen-sharing, (iii) built-in video recording function, and (iv) can be added or synced to calendar.
f) Slow or unstable internet connections would result in students being frequently disconnected during synchronous lecture discussions. These students may have difficulty joining the session rooms again and add stress to students.
g) Some instructors are with other family members which may result in disruptions during the class.
h) Assessment methods must be re-structured to minimize academic dishonesty while still training the students with the required numerical and analytical skills in solving word problems. It is therefore important to create exams that will minimize collaboration or reduce internet searching.
i) The difficulty of the provided assessment must be balanced with the given time frame. In addition, the time frame must also consider other factors, such as the time needed to scan and save their solutions, and the upload speed of their internet connection. These factors should not be neglected to promote fairness among students.

Table 2 shows how each DLPCA component addresses the different constraints of the online teaching and learning, and the proposed plans to minimize these constraints. The DLPCA strategy combines the use of asynchronous and synchronous techniques of teaching learning.

Asynchronous learning promotes a positive learning environment because it allows the students to feel more involved and responsible for their learning progress. However, with this method alone, students cannot get instant feedback and message from the instructor and vice-versa. This may also lead to students feeling disconnected from their instructors and be less motivated. Thus, it is coupled with a synchronous session using a reliable video conferencing platform. This provides a way for a more effective communication between instructors and students, which is important for clarifications, topic emphasis and instructor-student connection, especially during the challenging time of the pandemic.

3.1.3. The role of instructor, student and LMS

Though the pedagogical theories considered in the design of DLPCA are learner-centred, the roles of the instructor and the technology utilized are also important in the online classroom. In a learner-centred approach, the teachers mainly act as guide for instruction and provide the learning direction to students. They provide the necessary tools and resources that will aid in the students' development of their knowledge (Owusu-Agyeman et al., 2017). Students then must then take an active role in their own learning process and decisions throughout the course.

Meanwhile, the use of technology in modern systems of teaching and learning approaches have already been widely employed. The integration of instructional technology, such as lecture videos,

Table 2
Alignment of DLCPA components with online teaching and learning constraints and plans to minimize these constraints.

Component	Constraint Addressed	Plans to minimise constraints
Discover	a	• Lecture handouts, progress trackers, lecture videos, chemistry infographics, revised course syllabus, and web links to other online resources are uploaded in UST Blackboard Course site
Learn	b, c	• Lecture videos are uploaded in accessible and free of charge in a video streaming platform. • Infographic announcements are posted for students to be aware to the time frame for activities
Practice	d	• Detailed explanations of word problems • Self-assessment questions are available for each topic • Assigned numerical problems in from textbook
Collaborate	e, f, g	• Use of a free and stable video conferencing platform for online class. • Synchronous sessions are recorded and uploaded in the UST Blackboard Course site. • Conduct of team teaching/plenary mode of lecture delivery.
Assess	h, i	• Online assessments are deployed with multiple sets and a specified time for solving and submission of answers. • A wide time frame was recommended to allow students wider access specially those who may have limited internet connectivity.

online course delivery and online assessments, has also been found to promote the development of knowledge and skills of instructors and students alike (McConnell, 2006; Burden et al., 2016).

3.2. Organization and delivery of learning objectives

3.2.1. Revised course plan and checklists

During the initial shift to online instruction, course syllabi were reviewed and modified accordingly to ensure that students will still be able to complete their course (refer to Section 3.2.4.1). The revised course plan delivery contained weekly expectations of lessons, deadlines for submission of tasks, list of online reference materials, and modified grade components and distribution. In principle, the revised course plan delivery provided continuity and steadiness during the abrupt change of instruction.

Checklists are also recommended in the practice of online and flipped classes because students often preferred more structure in flipped classrooms (Brandon, 2020; O'Flaherty and Craig, 2015). Therefore, a progress tracker (Supplemental Information, SI-2) was created in addition to the revised course plan. The progress tracker contained the complete list of all topics in the module, the synchronous and asynchronous tasks for each lecture, and the specific topics included for each exam. The students can tick the appropriate boxes whenever they have accomplished the tasks, thus, keeping them on track with the formative and gradable requirements. Infographic-style weekly expectations announcements were also employed and posted in Blackboard and sent to the students through their university email at the beginning of each week. These announcements reminded students of the specific topics, new materials uploaded, and changes in schedule or exams, if any. Overall, these tools of disseminating information provided a substructure for the instructors and students to achieve learning milestones within the agreed period.

3.2.2. Asynchronous teaching and learning

The use of educational videos has shown positive impact to teaching and learning of chemistry even before the full transition to online lectures (Smith, 2014; Christensson and Jesper, 2014). All Analytical Chemistry and Physical Chemistry lecture videos are available to students at any time throughout the semester, and they can fully grasp the knowledge by simply watching it at their most convenient time and they can repeat it whenever some concepts were not understood. Thus, lecture videos offer flexibility and convenience on the part of the students and promote active learning by allowing them to replay parts or the whole video and increasing accessibility to students (Newton et al., 2014).

However, one drawback of using lecture videos in the flipped classroom is the fact that students are trusted to independently complete watching the recorded videos (Eichler and Peeples, 2016). If students do not successfully complete this task and make significant learning gains, then the completion of the synchronous session will be more difficult. The effect can be that students will not gain mastery of the intended learning outcomes. To address this potential drawback, problem-solving based SAQs were given at the end of each lecture video to promote the student's commitment in completing the lecture. Students were required to answer and submit the SAQs as a dedicated exercise that applies the problem-solving skills discussed in the video. In addition, these problem-solving SAQs present prospects for inquiry and personalisation of learning and avoid the passive watching of videos (Nerantzi, 2020).

Flores and Savage (2007) have previously shown that pre-recorded lecture materials aid in achieving a higher student performance and students pay more attention to classes that makes use of recorded lectures. There are plenty of chemistry videos of practically any topic are readily available on the internet. The main motivation of the authors in preparing their own video materials is the advantage of being more personal to students. Studies have also shown that students reported a higher level of engagement and expressed strong preference for multimedia created by their own instructor in an online course (Xu and Jaggars, 2014; Briggs, 2005). In fact, some students expressed their appreciation to the authors for the efforts they put in creating the videos. Some students also commented that they like listening to their instructors' voice especially when they add humour or explain difficult concepts using the local language. However, the weekly preparation of lecture video recordings was found to be a challenging and exhausting task on the instructors' end. This problem was resolved by effective collaboration and task distribution between the authors in developing the lecture videos and other online learning materials, such as handouts and SAQs for each topic. The concerted efforts helped amplify advantages of online instruction and lessen any drawbacks involved in online delivery.

The Analytical chemistry playlist shown in Fig. 2 **(a)** contains 11 videos with an average run time of 24 min and the longest video of 50 min and 35 s. There are 30 lecture videos prepared for Physical chemistry 1 playlist as shown in Fig. 2 **(b)**. The average run time is 15 min with the longest one being 36 min long. Ideally, the lecture videos should be kept short in length to fully engage the students. In this case, longer topics were divided into several shorter videos (i.e., segmentations). The technical know-how in creating lecture videos was the major challenge because the authors are not trained in making videos. The authors had to record their lectures in their own homes, resulting in lecture videos that are not as fancy as those produced with the help of experts. It is noted that lecture videos have a profound impact on how students process and comprehend the content. Therefore, a video editing software was used

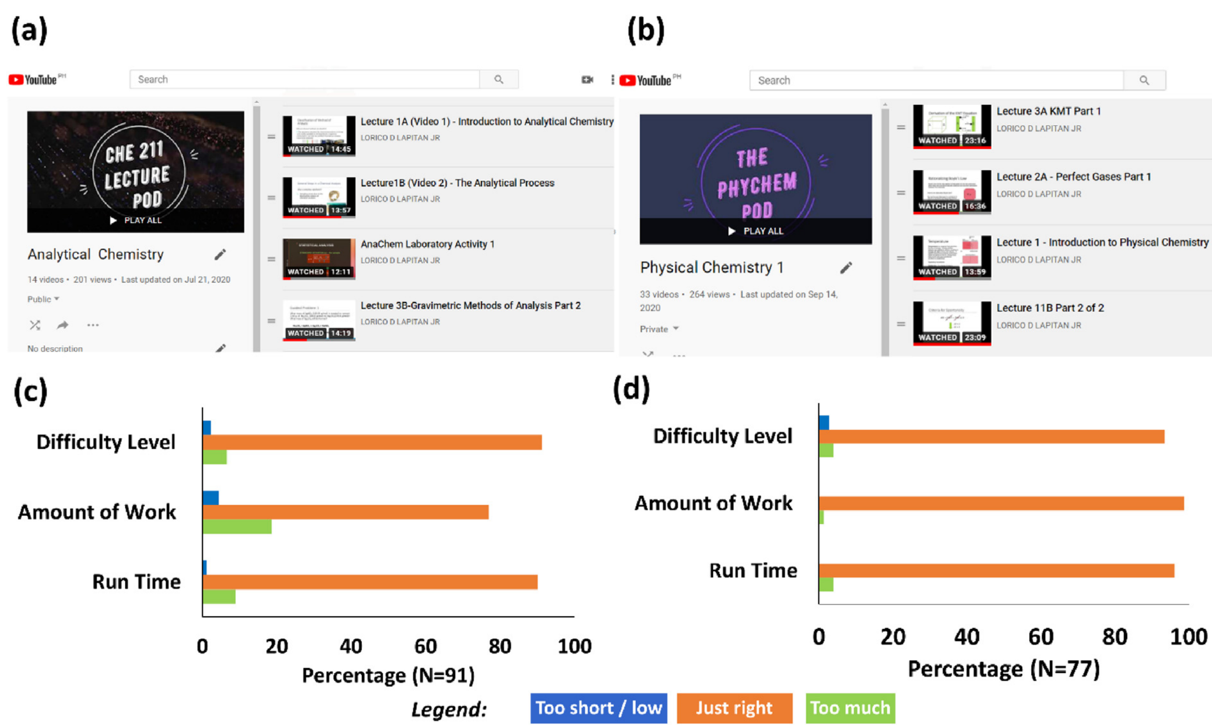

Fig. 2. Lecture video playlists in YouTube for **(a)** CHE 211 and **(b)** CHE 216. The student responses to the features of lecture videos for **(c)** CHE211 and **(d)** CHE 216. Work refers to the time spent in watching the video and answering the SAQs.

to further enhance the lecture videos. A close-ended question with "too short/ low", "just right", or "too much" option was surveyed regarding the difficulty level, amount of work, and run time for the lecture videos. It is encouraging that most of the respondents in CHE 211 and 216 responded "just right" when asked about the level of difficulty, amount of work, and run time for the recorded videos.

The quality of video lectures represents how the video lectures are designed or how it appears to the students (Lange and Costley, 2007). The lecture videos typically start with a 10 s introductory music and a welcome slide to stimulate the attention of the students. Thereafter, the topic to be discussed is introduced and expected learning outcomes are mentioned before proceeding to the actual discussion. A short summary of the lecture is given before the end slide. A common PowerPoint template design, and font type were used to ensure uniformity in all lecture videos for each Chemistry course. Table 3 shows the results on students' satisfaction in using the pre-recorded lecture videos. Majority of students in CHE 211 (92.3 %) and CHE 216 (97.4 %) strongly agree that the videos clearly stated the learning outcomes (entry 3.1). The calculated mean values for entry 3.1 are 4.44 and 4.68 for CHE 211 and CHE 216, respectively. Most of the respondents also strongly agree that our lecture videos are useful in attaining the objectives of the topic (entry 3.2) in CHE 211 (84.7 %) and CHE 216 (97.4 %). The mean values for entry 3.2 in CHE 211 and CHE 216 are 4.27 and 4.66, respectively. Most of the respondents in CHE 211 (73.7 %) and CHE 216 (91 %) agree that explanations of solutions for sample problems (entry 3.3) are easy to understand. The calculated mean for entry 3.3 is 4.03 and 4.35 for CHE 211 and CHE 216, respectively. Majority of respondents in CHE 211 (86 %) and CHE 216 (92.2 %) also agree that theories and concepts in the lecture videos were clearly presented in the video (entry 3.4). Most students in CHE 211 (71.5 %) and CHE 216 (76.7 %) also agree that there are enough guided problems discussed in the video (entry 3.5). The mean values for entry 3.5 in CHE 211 and CHE 216 are 3.85 and 4.08, respectively. These data suggest that students agree that there are sufficient guided problems discussed in the lecture videos.

Clarity of presentation is essential to ensure student engagement and ultimately learning. Audio and visual clarity of lecture videos is a concern among students in online classes because this can have a negative effect on how students perceive and comprehend instruction (Molnar, 2017; Lange and Costley, 2007). The production quality and the delivery of the content by the instructor are crucial for engaging the students. Poor audio and visual quality will ultimately decrease attention and understanding among learners (Molnar, 2017). Hence, a video editing software was used to ensure the images, videos and sound are as clear as possible before using the videos to deliver information. To enhance the audio intelligibility, the voice of the instructor was amplified, and extraneous sounds were removed that might distract students from listening to their instructors' voice. YouTube has a built-in subtitle function that allows text to accompany the narration and incremental audio and visual speed controls. These features can be used by students depending on their need for the video to be perceived manageable. A close-ended question with the "yes" or "no" option was also surveyed regarding whether visuals and audio recording are clear. Majority of respondents in CHE 211 and CHE 216 answered "yes" when asked if the visuals and audio components in the lecture videos are clear (Supplemental Information SI-3).

It is recognized that the learning environment of students differs from each other as well as the capacities of students in understanding the concepts. Common problems, such as power interruptions, unstable internet connection, and non-academic responsibilities are some hurdles encountered during asynchronous learning. These reasons contributed why some CHE 211 students found it difficult to keep in pace with the asynchronous online learning. The aesthetics, production values, and overall design of lecture videos all influence the learning process (Lange and Costley, 2007; Leacock and Nesbi, 2007). Hence, lecture videos were evaluated if they had a positive impact on the learning experience of stu-

Table 3
Distribution of students' response to Analytical chemistry (CHE 211) and Physical chemistry (CHE 216) questionnaire on lecture videos reported as frequency, percentage and mean for each entry. The total participant surveyed for Analytical chemistry and Physical chemistry are N = 91 and N = 77, respectively. The response for CHE 216 is shown in blue colour.

Table Entry	Statement	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Mean
3.1	The video tutorial's learning outcomes are clear	47(51.6%)	37(40.7%)	7(7.7%)	0(0%)	0(0%)	4.44
		54(70.1%)	**21(27.3%)**	**2(2.6%)**	**0(0%)**	**0(0%)**	**4.68**
3.2	The video tutorials are effective in helping me reach the learning objectives for each lecture .	41(45.1%)	36(39.6%)	12(13.2%)	2(2.2%)	0(0%)	4.27
		53(68.8%)	**22(28.6%)**	**2(2.6%)**	**0(0%)**	**0(0%)**	**4.66**
3.3	The explanation to word problems in the lecture video are easy to understand	31(34.1%)	36(39.6%)	20(22%)	4(4.4%)	0(0%)	4.03
		35(45.5%)	**35(45.5%)**	**6(7.8%)**	**1(1.3%)**	**0(0%)**	**4.35**
3.4	The theories (concepts) presented in the video lecture are clearly explained and easy to understand	32(35.2%)	46(50.5%)	12(13.2%)	1(1.1%)	0(0%)	4.20
		41(53.2%)	**30(39%)**	**6(7.8%)**	**0(0%)**	**0(0%)**	**4.45**
3.5	There are sufficient number of examples of guided word problems in the lecture video	29(31.9%)	36(39.6%)	11(12.1%)	13(14.3%)	2(2.2%)	3.85
		31(40.3%)	**28(36.4%)**	**11(4.3%)**	**7(9.1%)**	**0(0%)**	**4.08**
3.6	The video lectures are engaging to use. They are not tiresome or boring to watch	24(26.4%)	33(36.3%)	30(33%)	4(4.4%)	0(0%)	3.85
		36(46.8%)	**25(32.5%)**	**14(18.2%)**	**2(2.6%)**	**0(0%)**	**4.23**
3.7	I can describe (in my own words) the important concepts/facts discussed in the video lecture	20(22%)	46(50.5%)	22(24.2%)	3(3.3%)	0(0%)	3.91
		13(16.9%)	**50(64.9%)**	**13(16.9%)**	**1(1.3%)**	**0(0%)**	**3.97**
3.8	I can give an overview of the tutorial's subject matter	23(25.3%)	44(48.4%)	22(24.2%)	2(2.2%)	0(0%)	3.97
		15(19.5%)	**49(63.6%)**	**13(16.9%)**	**0(0%)**	**0(0%)**	**4.03**
3.9	I can present complex facts discussed in the videos illustratively	14(15.4%)	34(37.4%)	36(39.6%)	7(7.7%)	0(0%)	3.60
		11(14.3%)	**37(48.1%)**	**22(28.6%)**	**7(9.1%)**	**0(0%)**	**3.68**
3.10	I am able to work independently on typical questions like worded problems	23(25.3%)	37(40.7%)	28(30.8%)	3(3.3%)	0(0%)	3.88
		29(37.7%)	**38(49.4%)**	**9(11.7%)**	**1(1.13%)**	**0(0%)**	**4.23**

dents. Most of the students in CHE 211 (72.5 %) and CHE 216 (81.8 %) agree that they can describe the important concepts in the lecture video (entry 3.7). This is supported by a mean value of 3.91 (Agree) and 3.97 (Agree) for CHE 211 and CHE 216, respectively. The students in CHE 211 (73.7 %7) and CHE 216 (83.81 %) also agree that they can give an overview of the topic after watching the lecture video (entry 3.8). The mean values for entry 3.8 are 3.97 (Agree) and 4.03 (Agree) for CHE 211 and CHE 216, respectively. The students in CHE 211 (52.8 %; mean = 3.60) and CHE 216 (62.4 %) agree that they can present complex facts illustratively in the lecture video (entry 3.9). This is supported by the mean values of 3.60 and 3.68 for CHE 211 and CHE 216, respectively. Moreover, respondents in CHE 211 (66 %) agree (mean = 3.88) and CHE 216 (87.1 %) strongly agree (mean = 4.23) that they can work independently on typical word problems after watching the videos (entry 3.10). These data show that CHE 211 has a lower mean value for statements 3.8, 3.9, and 3.10 as compared to CHE 216. Again, these slightly lower mean scores were attributed to the 5-week intensive Special Term when CHE 211 was offered. It is highly suggested that enough time is necessary to fully understand the discussions in the lecture video. The mean of entries from 3.1–3.10 for CHE 211 and CHE 216 were calculated as 4.00 and 4.24, respectively. In general, CHE 211 students agree while CHE 216 students strongly agree that our pre-recorded lecture videos are effective in delivering the learning outcomes, engaging, and useful in their online learning. These results emphasize that lecture videos can reduce cognitive load of the students. The underlying premise of the cognitive load theory is that we have a limited amount of memory and overloading with information impedes learning (Abeysekera and Dawson, 2015). Students can watch the videos several times, pause and/or rewind portions of the videos as needed. This student-pacing may aid in better learning by reducing cognitive load (Esson, 2016).

3.2.3. Synchronous teaching and learning

The common misconception about flipped classrooms is that most people think only of videos. Bergmann et al. (2013) and Tucker (2012) highlighted that watching videos is not enough to make flipped learning effective. The collaborative interaction and learning activities that occur during the face-to-face (Bergmann et al., 2013; Tucker, 2012) or online setting (Nerantzi, 2020) is very important. Hence, synchronous lecture sessions were conducted using Google meet (Google Meet, 2019) or Zoom (Zoom, 2019). The synchronous meetings were also recorded for those students who were unable to attend the scheduled meeting and those who are struggling with internet connectivity. One of the benefits of the synchronous instruction is that it can provide students a schedule and sense of community. This also allowed instructors to feel the "whole-class" teaching experience and increase communication for instructor – student engagement. The synchronous sessions were dedicated mainly to reinforce difficult concepts and a summary of learning outcomes of the video lectures. During the synchronous sessions, students were asked to present and explain their solutions to their classmates and answer questions as they arose (Supplemental Information, SI-4). This was done to increase student participation and allowed them to present their alternative solutions to a problem. The instructors also made corrections (if necessary) to the solutions or answers that were presented by the students and answered any further questions on the problems. These activities provide an opportunity to devote more time at higher levels of Bloom's taxonomy (*i.e.,* applying, analysing, and evaluating) (Krathwohl, 2002).

The instructors have also requested the students to turn on their video cameras during synchronous sessions to promote visual communication. However, most students were unwilling to use their webcams and some reported that their webcams are not working properly. There are several possible reasons for non-video during synchronous meetings and these include: (i) students are shy to show their backgrounds particularly if there are family members present at home; (ii) feeling of not properly dressed or groomed during the synchronous session; (iii) computers have no webcam or the webcam are not working; and (iv) preference of students of being more comfortable with audio-only mode during online synchronous sessions. Therefore, it is difficult to find out whether students are really paying enough attention during the synchronous class. These reasons might have decreased the effectiveness of student-instructor engagement during synchronous online lectures. Therefore, it is advisable that plans should be taken into consideration to promote this vital component in an online class. Based on our personal experience, many students have the tendency to avoid asking questions to instructors in the usual traditional face-to-face classroom. Interestingly, we experienced more questioning from the students either made vocally or through the chat box of Google Meet. It seems that this kind of communication solves the hurdles in asking questions in a traditional lecture class. A possible reason for this behaviour is that students tend to be more active in asking questions when they are not visible in the "virtual" classroom.

The synchronous online lectures in Physical Chemistry 1 were conducted by the individual instructors during the second term of AY 2019–2020, while CHE 211 was conducted through team-teaching in the succeeding term (i.e., Special term, AY 2019–2020). The teamwork of the authors in teaching CHE 211 undeniably reduced the stress and burden of preparing materials for the online classes. In team-teaching approach, each instructor was given a specific set of topics to develop materials and teach synchronously. This arrangement gave enough time for the other instructors to prepare their online materials. The usual online synchronous sessions were taught by the instructor-in-charge of the meeting (i.e., module leader) while the other instructors are also present during the synchronous session (referred as plenary sessions). This arrangement gave the following advantages: (i) peer review of lessons, (ii) best practices of the instructor are shared among colleagues, (iii) standardized lectures were given to all students, (iv) the other instructors were given a chance to add something in the lecture, and (v) other instructors may give their inputs in answering questions from students. This team-teaching approach has been previously shown effective because it allows students to gain new insights from multiple perspectives and critically evaluate these perspectives (Anderson and Speck, 1998; Crawford and Jenkins, 2018; Tan et al., 2020). CHE 211 students reflected their appreciation towards this type of teaching approach during the survey and some of the comments are shown below:

> *"The whole plenary sessions for me is the most useful thing. I can ask questions that can benefit not just me but the whole batch too and vice versa."*
> *"At first, I had doubts doing the plenary session since all of the ChE students in my batch would be there and perhaps may be difficult to handle since it was a 3:100 ratio of instructors to students. However, it was a great experience getting to know my future colleagues, as well as the three instructors as I learned different sets of viewpoints from them, which in turn, helped me during this short term, may it be academic related or life-related."*
> *"One of the best features is that 3 instructors are able to provide input from their experiences in the industry giving the lesson clarity, and it makes it more interesting and motivating to hear these from professionals."*

The students were also asked in general of their experience of this synchronous teaching strategy (Supplemental Information, SI-3). Majority of students expressed that the instructors managed the team teaching effectively (94.5 %) and the plenary sessions provided a welcoming, interactive, and engaging virtual classroom (92.3 %). It is expected that large class size can increase the barriers related to student anonymity and passivity (Eichler and Peeples, 2016). However, Hoyt et al. (2010) highlighted that teaching a large enrolment course can be a very engaging and productive learning experience for students and a rewarding experience for the instructor through effective classroom management, careful planning, and ingenuity. The experience in teaching synchronous sessions led the authors to realize that it is important to connect with students through video streaming and frequently ask questions to gauge student's attention and learning. Moreover, it is also important that students present and discuss their solutions to problems to further increase student-teacher interaction.

3.2.4. Assessments and learning outcomes (LOs)

3.2.4.1. Change in course assessments and alignment with LOs. In most chemistry courses, assessments were originally given as exams, in-class group presentations, and individual problem sets. Problem sets are regularly given to students because solving relevant problems is indispensable to the understanding concepts, practice of numerical skills, and deepening knowledge of chemistry. Problem sets are referred here as self-assessment questions (SAQs) and module exams were the primary assessment tools employed in online CHE 211 and CHE 216. The number of items usually given in SAQs and the time-involvement are comparable to those in face-to-face lectures. This is to ensure the effectiveness of assignments would not be different. The SAQs were similar to the guided problems discussed in the lecture videos and were selected to fulfil the intended learning outcomes (LOs) of the module. At the very least, students were expected to watch the pre-recorded lecture video and answer the SAQs.

All chemistry courses offered to Chemical Engineering students used to have at least two major exams in a semester, i.e.,

Table 4
Alignment of Assessment with LOs in Analytical Chemistry (CHE 211) before and during COVID-19. Before COVID-19 is based on the course syllabus for Special Term of AY 2018–2019 while During COVID-19 is based on the revised course syllabus for Special Term 2019–2020. Legend: Fully Consistent (●), LO not Delivered (⊘), blank (no assessment conducted).

Module	Learning Outcomes (LO)	LO Alignment		Assessment Alignment	
		Before COVID-19	During COVID-19	Before COVID-19	During COVID-19
	LO1. Define important concepts and terminologies used in chemical analysis and differentiate the different methods of chemical analysis.	●	●	Quiz 1-A, Preliminary Exam, and SAQs	Quiz 1 and SAQs
1	LO2. Perform calculations on different concentration units and stoichiometry.	●	●	Quiz 1-B Preliminary Exam, SAQs	Quiz 2, Quiz Bee, and SAQs
	LO3. Describe and enumerate the steps involved in classical methods of analysis.	●	●		
2	LO4. Perform calculations in classical methods of analysis.	●	●	Quiz 2 Final Exam and SAQs	Quiz 3 and SAQs
	LO5. Construct titration plots and evaluate the feasibility of titration.	●	●	Quiz 3 Final Exam and SAQs	Quiz 4, Quiz Bee, and SAQs
3	LO6. Differentiate and describe the operation of some instrumental methods of analysis.	●	⊘	Quiz 4 Final Exam and SAQs	

preliminary exam and final exam and several quizzes. Now that assessments should be given online, academic integrity is one of the concerns of faculty members. In the case of CHE 216, it was decided that preliminary and final exams were replaced by module quizzes as everyone was still adjusting to the online instruction and provide more time for students to understand the lessons. The same decision was made for CHE 211 because of the short and intensive 5-week period during the special term of 2020. The assessments and learning outcomes before COVID-19 (i.e., face-to-face) and during COVID-19 (i.e., online) for CHE 211 are summarized in Table 4. Table 4 shows how the LOs are aligned with the given assessment before and during COVID-19. The assessments with their corresponding weightings to the final grade before COVID-19 special term (AY 2018–2019) include quizzes (40 %), SAQs (10 %), preliminary exam (25 %) and final exam (25 %). However, assessments during COVID-19 special term (AY of 2019–2020) only included exams (70 %) and SAQs (30 %). Module 1 and Module 2 contained a large number of topics and were divided into smaller quizzes. There were 4 computational exams given and 2 conceptual assessments given in the form of a quiz bee.

Table 5 summarizes the alignment of assessments and change in LO's for Physical Chemistry during the 2nd Term of AY 2019–2020. The class suspensions at the start of community lockdown led to less lecture hours in CHE 216. Hence, the instructors decided to transfer module 4 (with LO-4 and LO-5) to next the Physical Chemistry course. The assessments in CHE 216 include 3 module quizzes and SAQs. The first exam and SAQs was completed in regular classroom set-up before the community lockdown and the other two exams were completed online. Each online quiz was scheduled and conducted asynchronously. To minimize cheating, each student received a unique set of questions for the other two exams with a similar level of difficulty for each question set. A solution template was also provided where they can discuss their plan on how to solve the assigned problem and show the detailed calculations. Their solutions were submitted through specific submission links in the Blackboard portal before the deadline. It was expected that this strategy decreased the feasibility of cheating because each student must give a unique plan to solve the problem and solution. The original percentage of each component module for Physical Chemistry 1 (CHE 216) were module 1 (25 %), 2 (25 %), 3 (30 %), and 4 (20 %). The shift to online instruction necessitated an adjustment in the module weights. The corresponding revised module weights were module 1 (35 %), module 2 (35 %) and module 3 (30 %).

3.2.4.2. Student survey on assessment and learning outcomes. The student experiences in accomplishing the assessments were examined. Table 6 shows that most of the students in CHE 211 (75.9 %) agree (mean = 4.07) and majority of students in CHE 216 (94.8 %) strongly agree (mean = 4.55) that the number of SAQs is enough to achieve the declared learning outcomes of the module (entry 6.1). However, only 52.8 % of students in CHE 211 agree (mean = 3.49) that they can easily answer the SAQs after watching the videos compared to those who strongly agree (mean = 4.31) in CHE 216 (89.7 %) (entry 6.2). The somewhat lower mean for CHE 211 might be due to the limited time for students in CHE 211 to fully understand the videos and apply the problem-solving skills discussed in the guided problems. Only 60.5 % of CHE 211 students agree (mean = 3.75) that there is enough time to answer the SAQs as compared to those who strongly agree (mean = 4.51) in CHE 216 (93.5 %) (entry 6.3). Unfortunately, it is counterproductive that some students find SAQs as mere requirements rather than authentically assessing their learning gains. Our survey suggests that students must be given enough time to watch the videos and a longer period of submission of SAQs. In this manner, students will realize the importance of SAQs in achieving the desired numerical solving skills rather than simply submitting the SAQs as a gradable component.

The students were also asked whether the adjustments in the number of exams are enough to assess the student learning and understanding of the course (entry 6.4). Most of the respondents in CHE 211 (69.3 %) agree (mean = 3.89) and majority of respondents CHE 216 (94.8 %) strongly agree (mean = 4.57) that there are enough exams. However, 13.2 % of students in CHE 211 disagreed on this statement and expressed that additional exams should have been given (entry 6.4). We decided to give only 4 module exams within the 5-week special term of AY 2019–2020.

In CHE 216, quiz 2 and 3 were conducted asynchronously with a recommended 24-h window for the submission of answers to allow students wider access, especially those who may have limited internet connectivity. Although internet connectivity within Metro Manila is good, it is not clear if the same situation exists in other regions of the country. Nonetheless, the majority of respondents in CHE 216 (93.5 %) strongly agree (mean = 4.47) that timed-release

Table 5
Alignment of Assessment with LOs in Physical Chemistry (CHE 216) before and during COVID-19. The before COVID-19 refers to the course syllabus before community lockdown during 2nd Term AY 2019–2020 while during COVID-19 is based on the same term after switching to online instruction. Legend: Fully Consistent (●), LO not Delivered (⊘), N/A (Not Applicable), blank (no assessment conducted).

Module	Learning Outcomes (LO)	LO Alignment		Assessment Alignment	
		Before COVID-19	During COVID-19	Before COVID-19	During COVID-19
1	LO1: Describe the states of matter through the ideal gas law and real gas equations of states, and apply the kinetic theory of particles, Boltzmann distribution and Graham's law of diffusion.	●	N/A	Quiz 1 and SAQs	N/A
2	LO2. Critically evaluate the internal energy, enthalpy, entropy, Gibbs free energy and Helmholtz functions and their physical applications in energetic cycles and thermodynamics.	●	●	N/A	Quiz 2 and SAQs
3	LO 3. Relate the Gibbs free energy with the spontaneity of chemical changes and equilibrium and explain the dependence of chemical potential on pressure and temperature.	●	●	N/A	Quiz 3 and SAQs
4	LO 4. Interpret phase diagrams and discuss phase equilibria in terms of chemical potentials.	●	⊘	N/A	
	LO 5. Explain thermodynamics and phase equilibria with Gibbs free energy, and Clapeyron and Clausius-Clapeyron equations.	●	⊘	N/A	

Table 6
Distribution of students' response to Analytical chemistry (CHE 211) and Physical chemistry (CHE 216) questionnaire on Assessment type and strategy reported as frequency, percentage and mean for each entry. The total participant surveyed for Analytical chemistry and Physical chemistry are N = 91 and N = 77, respectively. The response for CHE 216 is shown in blue colour.

Table Entry	Statement	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Mean
6.1	The total item of self-assessment questions (SAQs) after each lecture is sufficient to achieve the learning outcomes for lecture or topic.	34(37.4%)	35(38.5%)	16(17.6%)	6(6.6%)	0(0%)	**4.07**
		47(61%)	26(33.8%)	3(3.9%)	1(1.3%)	0(0%)	**4.55**
6.2	I can easily answer the self-assessment questions (SAQs) after watching the pre-recorded video lecture	14(15.4%)	34(37.4%)	27(29.7%)	15(16.5 %)	1(1.1%)	**3.49**
		32(41.6%)	37(48.1%)	8(10.4%)	0(0%)	0(0%)	**4.31**
6.3	There is enough time to work on the self-paced learning materials (e.g. to watch lecture videos and submit SAQs)	25(27.5%)	30(33%)	26(28.6%)	8(8.8%)	2(2.2%)	**3.75**
		45(58.4%)	27(35.1%)	4(5.2%)	1(1.3%)	0(0%)	**4.51**
6.4	The total number of quizzes in CHE 211 (CHE 216) is enough to assess student learning of the course.	30(33%)	33(36.3%)	16(17.6%)	12(13.2 %)	0(0%)	**3.89**
		49(63.6%)	24(31.2%)	3(3.9%)	1(1.3%)	0(0%)	**4.57**
6.5	The timed release of questions during a Quiz is a good training to develop my problem-solving skills.	16(17.6%)	36(39.6%)	26(28.6%)	12(13.2 %)	1(1.1%)	**3.59**
		41(53.2%)	31(40.3%)	5(6.5%)	0(0%)	0(0%)	**4.47**
6.6	The synchronous virtual games (quiz bee) is a good strategy to assess the students understanding of the theories and concepts in a fun and stimulating environment.	63(69.2%)	17(18.7%)	6(6.6%)	5(5.5%)	0(0%)	**4.52**

and submission of quizzes for Physical chemistry 1 is a good way to train their problem-solving skills (entry 6.5). The wide time frame for the online submission was also an attempt to mitigate the reduced access to Blackboard online submission from students currently staying in other regions of the Philippines with intermittent internet connections. However, a wide asynchronous window period might pose academic integrity issues. Limiting the time of unsupervised assessment format restricted the amount of time for any potential collaboration. This learning experience was applied in giving assessments in CHE 211 in the succeeding term.

A total of four quizzes were given synchronously for CHE 211. In the first quiz, six problem solving questions were given to each student to answer in 60 min. These problems were given in three consecutive batches with 2 problems and 20 min per batch. To promote academic integrity, the instructors modified the dissemination quiz questions for the succeeding quizzes. Two problem solving questions were still given per batch, however, nine different sets were deployed. To ensure the same level of difficulty, only the given values and questions were rephrased. At the request of students, the time allotted per batch was increased to 30 min to account for the time used for downloading the questions and uploading the answers. These modifications, despite prolonging the time allotment per batch, resulted in a significant decrease in student performance for Quiz 2 (Supplemental Information 9, SI-9). Interestingly, the students were able to positively accept the adjustments for Quiz 3 and Quiz 4, resulting in significant increase in student performance for both quizzes as revealed by ANOVA analysis (Supplemental Information 9, SI-9).

Even with time adjustments, 57.2 % of CHE 211 students agree (mean = 3.59) that the timed-release of the exam questions provided good training to develop their problem-solving skills (entry 6.5). The survey suggests that sufficient time is important in assessing the performance of students in courses requiring intensive numerical calculations. The concepts and theories in Analytical chemistry were assessed using a quiz bee (entry 6.6). The motivation of doing this activity is to promote student-student interaction and provide an environment for active student participation. Most of the respondents in CHE 211 (87.9 %) strongly agreed (mean = 4.52) that assessment of concepts through online game (i.e., quiz bee) provided a fun and stimulating environment. However, some respondents found this assessment strategy neither effective (6.6 %) and some students disagreed (5.5 %) that quiz bees are effective in assessing the concepts learned. This observation was attributed to the various preferences of students on the type assessment. Another possible reason is that some students have unstable internet and affect their ability to quickly send their answers during the quiz bee. Overall, the majority of students in CHE 211(Mean = 3.88) students agree and CHE 216 (Mean = 4.48) students strongly agree that our self-assessment questions SAQs and exam strategy is sufficient and effective in assessing the understanding of the students of the topics in both calculations and theory.

4. Analysis of DLPCA teaching-learning experience

4.1. Impact on student learning experience

The perception and satisfaction of students regarding their DLPCA experience is discussed in this section. It is important that online teaching and learning strategy is laid-out and clearly discussed to the students. In terms of percentage, majority if not all the respondents in CHE 211 (91.2 %) and CHE 216 (100 %) agreed that there was a clear plan (entry 7.1) on how the courses were converted into an online class. The mean values for entry 7.1 are 4.47 and 4.70 for CHE 211 and CHE 216, respectively. The regular posting of tasks and deliverables to students further helped them understand the overall structure of the strategy, thus, resulting in a better learning process. This feedback is important because this will allow students to set their expectations in the new learning environment and will give them an impression of order and continuity (Table 7).

Majority of the respondents in CHE 211 (93.4 %) and CHE 216 (96.1 %) agreed that they had received a clear set of instructions for the weekly tasks expected from them (entry 7.2). The calculated mean for entry 5.2 were 4.63 and 4.65 for CHE 211 and CHE 216, respectively. This feedback is also important because this will provide students an overview of their weekly tasks, thus, giving them the chance to manage and make use of their time more efficiently. The most significant difference between online and traditional classrooms is that students and instructors cannot see and communicate with each other face-to-face. Hence, DLPCA combines a balance of synchronous and asynchronous components to engage the diverse personalities of students in a more inclusive way and maximizes opportunities for self- and guided learning. Most of the respondents agreed that the DLPCA strategy is balanced (entry 7.3) with a mean of 4.11 and 4.65 for CHE 211 and CHE 216, respectively. The term “balanced” refers to having sufficient and complementing mixture of asynchronous (lecture videos and SAQs) and synchronous (online discussion and consultation) teaching strategies. In addition, the mean values were determined for entry 7.4 to be 4.32 and 4.48 for CHE 211 and CHE 216, respectively. These data suggest that students strongly agreed that the synchronous component allowed them to easily express their feedback, concerns, and ask questions about the lecture materials (entry 7.4).

The balanced blended approach can help students establish active learning habits such as proactiveness (entry 7.5). The mean values for entry 7.5 were calculated as 4.27 and 4.29 for CHE 211 and CHE 216, respectively. These results suggest that the DLPCA strategy enabled students to develop a desirable active learning habit. The balanced online strategy also increases students’ sense of responsibility for learning (entry 7.6). The calculated mean values for the entry 7.6 are 4.42 and 4.35 for CHE 211 and CHE 216, respectively. Some of the students’ comments in CHE 211 and CHE 216 related to the balanced online learning strategy are presented below:

> *[CHE 211] “The best thing about the online learning strategy is the balance between synchronous meetings and asynchronous videos. Since the pre-recorded videos are sharp and concise, they can be repeated multiple times before the synchronous meeting can start. This way, I can better understand the lesson and prepare for the meeting, but still anticipate for the synchronous session in order to gather more detailed information about the topics.”*
> *[CHE 211] “The best thing was the asynchronous and synchronous discussion for the lectures because there is balance with self-paced learning and synchronous learning.”*
> *[CHE 216] “Asynchronous and synchronous lectures were balanced which is good especially when there comes a technical difficulty particularly the poor internet connection.”*

The general acceptance and satisfaction of the students regarding the DLPCA learning strategy was emphasized in entry 7.7. Majority of students in CHE 211 (72.5 %) and CHE 216 (96.1 %) are satisfied with the online strategy. The calculated mean for entry 7.7 were 3.91 and 4.48 for CHE 211 and CHE 216, respectively. A relatively lower agreement was observed among CHE 211 students which may be attributed to the short intensive period of the Special Term resulting in shorter time allotted for accomplishing tasks and studying the lessons. This might have affected the understanding and appreciation of the topics in CHE 211, placing the

Table 7
Distribution of students' response to Analytical chemistry (CHE 211) and Physical chemistry (CHE 216) questionnaire on the structure of online instruction and student attributes reported as frequency, percentage, and mean for each entry. The total participant surveyed for CHE 211 and CHE 216 are N = 91 and N = 77, respectively. The response for CHE 216 is shown in blue colour.

Table Entry	Statement	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Mean
7.1	There is a clear plan on how CHE 211 (CHE 216) will be delivered using an online strategy.	51(56%)	32(35.2%)	8(8.8%)	0(0%)	0(0%)	4.47
		54(70.1%)	23(29.9%)	0(0%)	0(0%)	0(0%)	**4.70**
7.2	A clear set of direction is given for specific tasks that are expected to achieve each week.	64(70.3%)	21(23.1%)	5(5.5%)	1(1.1%)	0(0%)	4.63
		53(68.8%)	21(27.3%)	3(3.9%)	0(0%)	0(0%)	**4.65**
7.3	The asynchronous (watching video lectures, answering SAQs) and synchronous (live online classes via Google Meet) components of CHE 211 (CHE 216) are balanced and provided a self-paced learning environment.	33(36.3%)	39(42.9%)	15(16.5%)	4(4.4%)	0(0%)	4.11
		52(67.5%)	23(9.9%)	2(2.6%)	0(0%)	0(0%)	**4.65**
7.4	I can easily give my feedback, concerns, and questions to my instructor about video tutorials through live online platforms (e.g. Google Meet).	49(53.8%)	23(25.3%)	18(19.8%)	1(1.1%)	0(0%)	4.32
		45(58.4%)	25(32.5%)	6(7.8%)	1(1.3%)	0(0%)	**4.48**
7.5	I am committed to work for my own learning success by pro-activeness in searching for more information about the subject matter.	39(42.9%)	38(41.8%)	14(15.4%)	0(0%)	0(0%)	4.27
		33(42.9%)	33(42.9%)	11(14.3%)	0(0%)	0(0%)	**4.29**
7.6	I am committed to work for my own learning success by developing my time-management.	43(47.3%)	35(38.5%)	12(13.2%)	1(1.1%)	0(0%)	4.32
		45(58.4%)	25(32.5%)	5(6.5%)	1(1.3%)	1(1.3%)	**4.45**
7.7	Altogether, how satisfied are you with the online learning strategy?	20(22%)	46(50.5%)	22(24.2%)	3(3.3%)	0(0%)	3.91
		42(54.5%)	32(41.6%)	2(2.6%)	0(0%)	1(1.3%)	**4.48**

students in a very stressful situation. In the case of CHE 216, the first half of the semester was conducted in face-to-face instruction (before the community lockdown) and the second half of the term was conducted online. The longer period of the second term (5 months) has spread the workload of students in CHE 216 resulting in a very high acceptance of the online strategy. The overall mean of entries from 7.1–7.7 for CHE 211 and CHE 216 were calculated as 4.23 and 4.53, respectively. These suggest that, in general, students in both courses strongly agreed the DLPCA strategy has a clear laid-out plan, has provided a balance of synchronous and asynchronous components, has promoted active learning habits, and has been accepted by the students as an alternative to face-to-face setup. One possible reason for the high acceptance among students is that they were able to establish a routine towards the end of the semester. DLPCA provides a cohesive strategy where students know what to prepare before going to class and are reassured knowing that any questions that they would have will be answered during the synchronous sessions.

Open-ended questions regarding the students' general impression of the DLPCA strategy were examined using word clouds. Word cloud generates an image containing the most frequently used words from the comments being analyzed – the more frequently the word is used, the larger it will appear in the image (Bletzer, 2015). It is possible to look for specific patterns of words and phrases, or the lack thereof, in any text data by simply examining frequencies in a word cloud. Further interpretations of the word cloud can be carried out by detailed analysis of the responses (DePaolo and Wilkinson, 2014). Three themes related to the learning experience were identified, i.e. (i) the best experience in the online course, (ii) worst experience in the online course, and (iii) suggestions to improve the online course.

4.2. Theme 1: best experience

The word cloud of the feedback received from CHE 211 and 216 students are shown in Fig. 3**a** and **b**, respectively. The following three major topics emerged for CHE 211: (1) questions, (2) videos, sessions, lessons, and (3) asynchronous, strategy, lecture, instructors, more, time. The frequency table and graph for best experience are presented in Supplemental Information SI-6. The word "questions" was mentioned frequently because students can easily raise their questions and instructors can entertain all their questions during synchronous sessions. The second major topic includes words like "videos", "sessions", and "lessons". The production of pre-recorded videos was appreciated by the students as it makes online learning easier. Further clarifications and explanations for complex lessons were done during the synchronous discussions. The third major topic included words such as "asynchronous", "strategy", "lecture", "instructors", "more", "time". The respondents were optimistic as they enjoyed the learning strategy and emphasized the efficiency of content delivery and the ability to control the pace of learning. The students also emphasized the enthusiasm as well as the positive attitude of the instructors that was reflected throughout the recordings.

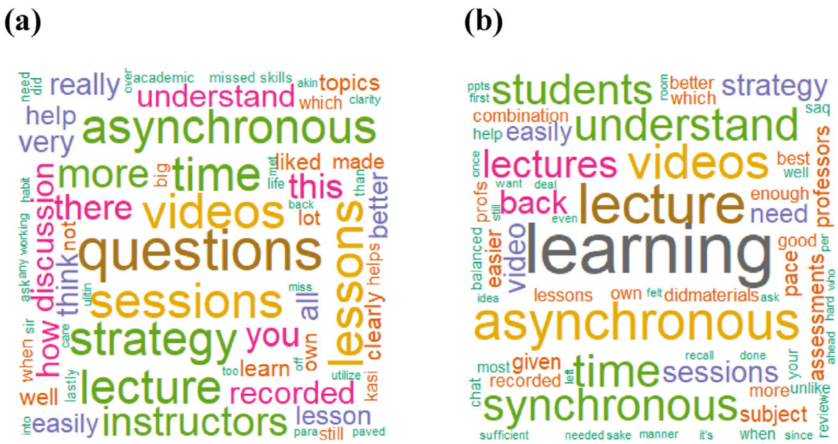

Fig. 3. Word cloud analysis on the best experiences in the online teaching and learning in (a) CHE 211 and (b) CHE 216.

Four major topics emerged for CHE 216: (1) learning, (2) lecture, (3) videos, asynchronous (4) students, time, understand, synchronous. Like CHE 211, students expressed that their best experience in online learning is the availability of pre-recorded lecture videos which is an essential component of asynchronous learning. Students also appreciate the synchronous sessions because it provided a platform to clarify difficult topics that were discussed in the video. Students also like the amount of time made available to them in the course. The blended learning strategy allowed them to manage their time well and understand the topics in CHE 216. Overall, analysis shows the positive impact of using pre-recorded video lectures in online learning depends on good planning and balanced integration of asynchronous and synchronous components. However, it should be noted that video lectures are not alternative options to face-to-face setup, but an essential supplementary tool in achieving the learning outcomes of the modules in online learning.

4.3. Theme 2: worst experience

Three major topics emerged in the word cloud for CHE 211 on the student's worst experience (Fig. 4a). Among these responses included (1) quizzes/quiz, (2) time, and (3) internet. The word "time" refers to the insufficient amount of time allotted for quizzes. The frequency table and graph for worst experience are presented in Supplemental Information SI-7. Some students in CHE 211 expressed their frustration that exam time is too fast-paced. The exam conditions gave them an impression of being rushed to analyze, answer, and upload their solutions. Although the exam questions were prepared to be similar to the one discussed in the online session, some students still find answering the quizzes (i.e., exams) stressful because the difficulty level of the questions are different from the ones discussed in the guided problems and SAQs. Several students were also affected by unstable internet connection in CHE 211 online class. Interestingly, the word cloud for CHE 216 (Fig. 4b) showed the most frequent keyword "none" for their worst experience. Most students appreciated the online strategy and commended their instructors for providing course materials that were sufficient to understand the topics fully. "Internet" and "time" were also the second most frequent words in the feedback. Internet connectivity issues which affected their participation during synchronous sessions and their timely submission of SAQs also contributed to the worst experience of students in their online CHE 216 course although these were mentioned to a lesser extent.

4.4. Theme 3: suggestions for improvement

The students were also asked about how they would like to experience their online classes in the succeeding semesters. The goal is to determine the enhancements to the DLPCA strategy and to make the students' learning experience more satisfying. The major topics that emerged in CHE 211 are (1) "more", (2) "quizzes", "synchronous" (3) "think", (4) "time", "lecture", "problem". The frequency table and graph for suggestions for improvement are presented in Supplemental Information SI-8. Most students conveyed that more quizzes, diverse guided problems during synchronous discussion and other forms of assessments must be included to compensate for low scores in their exams. Students also expressed their concern regarding the time devoted in watching the lecture videos and submitting SAQs. Specifically, flexibility in terms of extending the deadlines of SAQs for a day or two would be ideal. The words like "professors" and "instructors" also appeared in the word cloud because the students are appreciative of their teachers' efforts in their online class (Fig. 5).

The word cloud for CHE 216 showed the following 2 major topics (1) "course", "professor", "time" (2) "learning lecture", "videos", "strategy", "good". Some students expressed that additional problems must be given, and submission deadlines of assessments must be flexible. In general, there is high satisfaction of the DLPCA strategy among CHE 216 students. The students also acknowledged that CHE 216 course provided a clear structure during the quick transition to online instruction. Students expressed their desire to continue with the DLPCA strategy and credited their teachers for the commendable efforts made in their online class.

4.5. Impact on student performance

To further investigate the impact of DLPCA on student performance, the grade distribution for Special Term 2018–2019 (face-to-face) and Special Term 2019–2020 (online) for CHE 211 were compared and summarized in Fig. 6. Students are given a 5-point numerical grade which corresponds to 1.00 as the highest and 5.00 as the failed grade at the end of the semester. The grade WP corresponds to those students who withdrew with permission while the grade INC corresponds to incomplete. A grade of INC is given if a student failed to take the final examinations or to submit a major requirement of a course on account of illness or other valid reasons (UST Student Handbook, 2018).

Although the assessment weightings were different in the face-to-face and online semester, the content and variety of questions stayed the same. Interestingly, the final grade distribution during the online Special Term rendered a comparable grade distribution

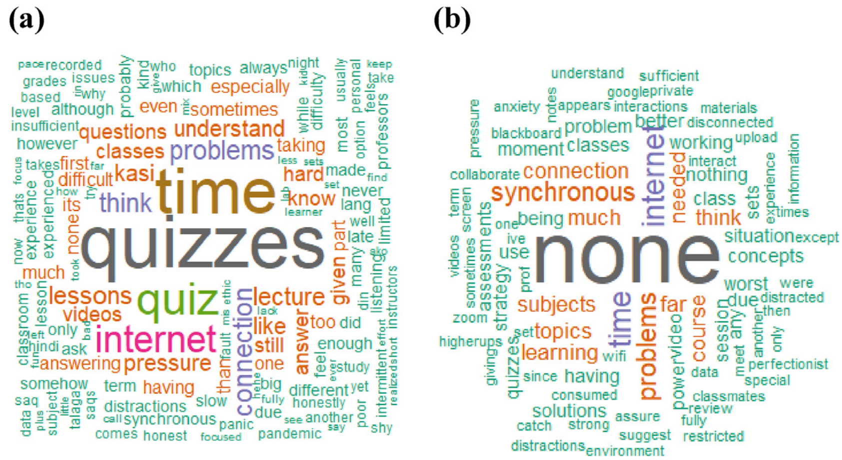

Fig. 4. Word cloud analysis on the worst experiences in the online teaching and in (a) CHE 211 and (b) CHE 216 courses.

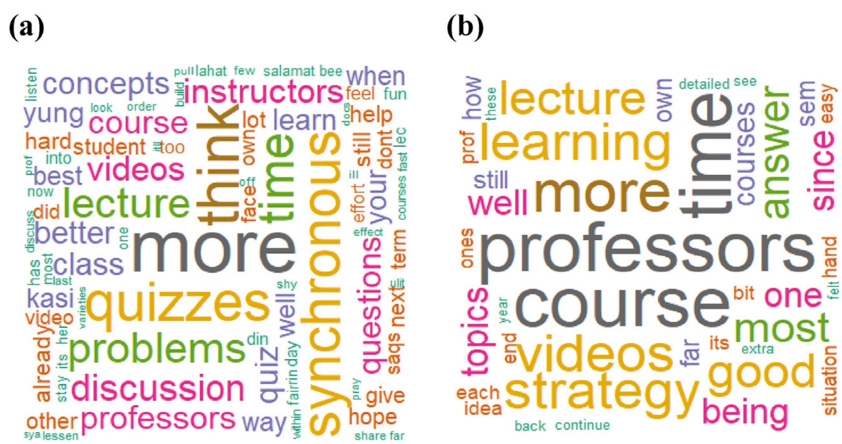

Fig. 5. Word cloud analysis on further improvements in the online teaching and learning in (a) CHE 211 and (b) CHE 216 courses.

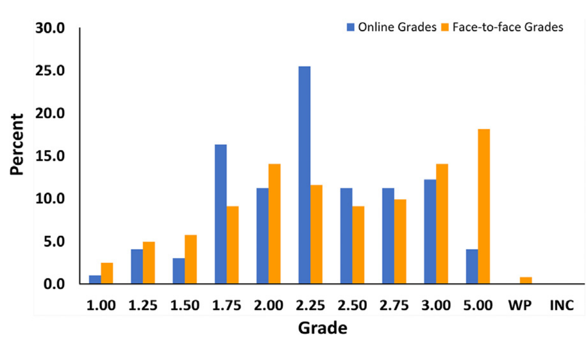

Fig. 6. Comparison of the grade distribution, as a percentage of students earning each grade, for the online group (3 sections, n = 98) and the face-to-face group (3 sections, n = 121) in Analytical chemistry.

in face-to-face Special Term. The most evident changes can be seen from the grades 1.75, 2.25 and 5.00. The percentage of students who got “1.75” nearly doubled (online = 16.3 %, face-to-face = 9.1 %) while those who got “2.25” more than doubled (online = 25.5 %, face-to-face = 11.6 %) in the online setting. On the other hand, the percentage of students who got “5.00” or failing grade became significantly lower (online = 4.1 %, face-to-face = 18.2 %) in the online setting. Interestingly, no student was given a grade of “WP” or “INC” in the online flipped classroom. These trends in the grade distribution could indicate that the DLPCA strategy positively impacted the students’ performance. To further verify the observed changes from the grade distributions between online and face-to-face, Welch *t*-test was used to analyse the data. Results ($p = 0.0002962$ and $p = 0.00306$) showed that online grades are indeed higher than face-to-face grades (Supplemental Information 10, SI-10). Unfortunately, the grade distributions between online (i.e., 2nd Term, AY 2019–2020) and previous face-to-face classes in CHE 216 cannot be compared. The community lockdown happened in mid-March 2020 which resulted to combination of face-to-face and online instruction for CHE 216. Hence, the performance of students during 2nd term cannot be assumed the same for the previous face-to-face classes.

4.6. Instructor observation

The instructor’s observations can be used to provide information on the effectiveness of flipped classroom in a qualitative perspective (Fautch, 2015). Instructors also reflected upon their experience while transitioning to online instruction and how DLPCA strategy played an important role in continuing chemistry education during the COVID-19 pandemic. One of the positive outcomes using the DLPCA strategy was the introduction of new technological teaching tools for the instructors. The switch to online instruction resulted in all instructors utilizing synchronous video conferencing tools, online assessments tools, and pre-recorded lecture videos. These changes have the potential to have long term positive impacts on instruction. Specifically, the production of self-made lecture videos, although a time-consuming process, can be a permanent teaching tool. The pre-recorded lecture videos will certainly be useful for the next semesters and will be a part of other innovative learning activities.

The transition to online learning also presented a big challenge to decide which online technology is best suited for lectures. It is very easy for instructors to be overwhelmed by the sheer number of educational platforms and online resources available. However, the DLPCA strategy streamlined all available online resources into an organized strategy. The DLCPA strategy also involved collaboration and delegation of workload (e.g., creating video lectures, construction of new activities, team teaching) among instructors which led to higher-quality learning materials. Additionally, the exchange of ideas helped instructors better plan for giving assessments.

Through the instructors' perspective, the DLPCA strategy also showed great impact on the students' learning. Online education has resulted to different kinds of difficulties which has somehow affected the progress of students in understanding the topics in their lecture courses. The implementation of flipped classroom learning is expected to prepare the students to participate in more interactive learning activities that require higher-order cognitive skills (Cowden and Santiago, 2016). Another great benefit for the DLPCA strategy is that synchronous sessions were recorded and uploaded in Blackboard for their exclusive use, and these capture the instructor's presentation, class discussions and the participations as they occur. The availability and accessibility of the videos is considered to have a positive effect on student learning as no student requested to repeat explanations on complex topics presented in the videos. Comparing to previous semesters where students usually ask instructors to clarify difficult concepts and calculations, this shows that DLPCA offers effectiveness, flexibility, and convenience to online learning.

Regarding the completion of SAQs, all students completed the task properly which may be because SAQs were also required as a gradable assessment. In previous semesters, the solutions to SAQs were primarily discussed by the instructor in the classroom. During the online term, students were randomly asked by the instructor to share their calculations during synchronous sessions. This activity trains students to extract information from the SAQs, organize solutions, communicate their knowledge, and develop a deeper level of thinking. Interestingly, some students would raise questions on the solutions of their classmates which encourages the exchange of ideas between students. Lastly, the team teaching conducted by the instructors had a positive effect on the students. The presence of all instructors during the class sessions allowed students to gain insights from each instructor.

5. Concluding remarks

The COVID-19 pandemic has opened venues for online teaching with a completely new outlook for educators and learners. Online education requires teachers to change from the old teaching paradigm to new teaching methods that also matches with technology. Consultation with students regarding the teaching style is important to check if the students are keeping up with the lecture and helps identify various aspects of online teaching that needs to be adjusted accordingly. This paper presented the DLPCA strategy that paved the way for transition from traditional face-to-face to online instruction during the pandemic. DLPCA consists of asynchronous learning using pre-recorded videos and synchronous session of live exchanges. The major lessons of using DLCPA strategy during the lockdown were (i) asynchronous teaching using lecture videos allowed students to progress at their own pace because they can repeatedly watch the videos at any time, (ii) checklists such as progress trackers and weekly guides helped students organize and manage their tasks, and (iii) asynchronous assessments were effective in addressing problems with slow internet connectivity. However, preventive measures must be in place to prevent unauthorized student collaboration and internet searching. In addition, the benefits of DLCPA outweighs the costs in time associated with the preparation of pre-recorded lecture videos. The various insights and results discussed in this paper could be adapted for designing synchronous and/or asynchronous components of online, flipped, or hybrid classes. In addition, DLPCA strategy can be applied in future events such as disruption of classes due to inclement weather conditions, and emergency situations when a faculty member cannot be physically present in a classroom due to health reasons.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ece.2021.01.012.

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